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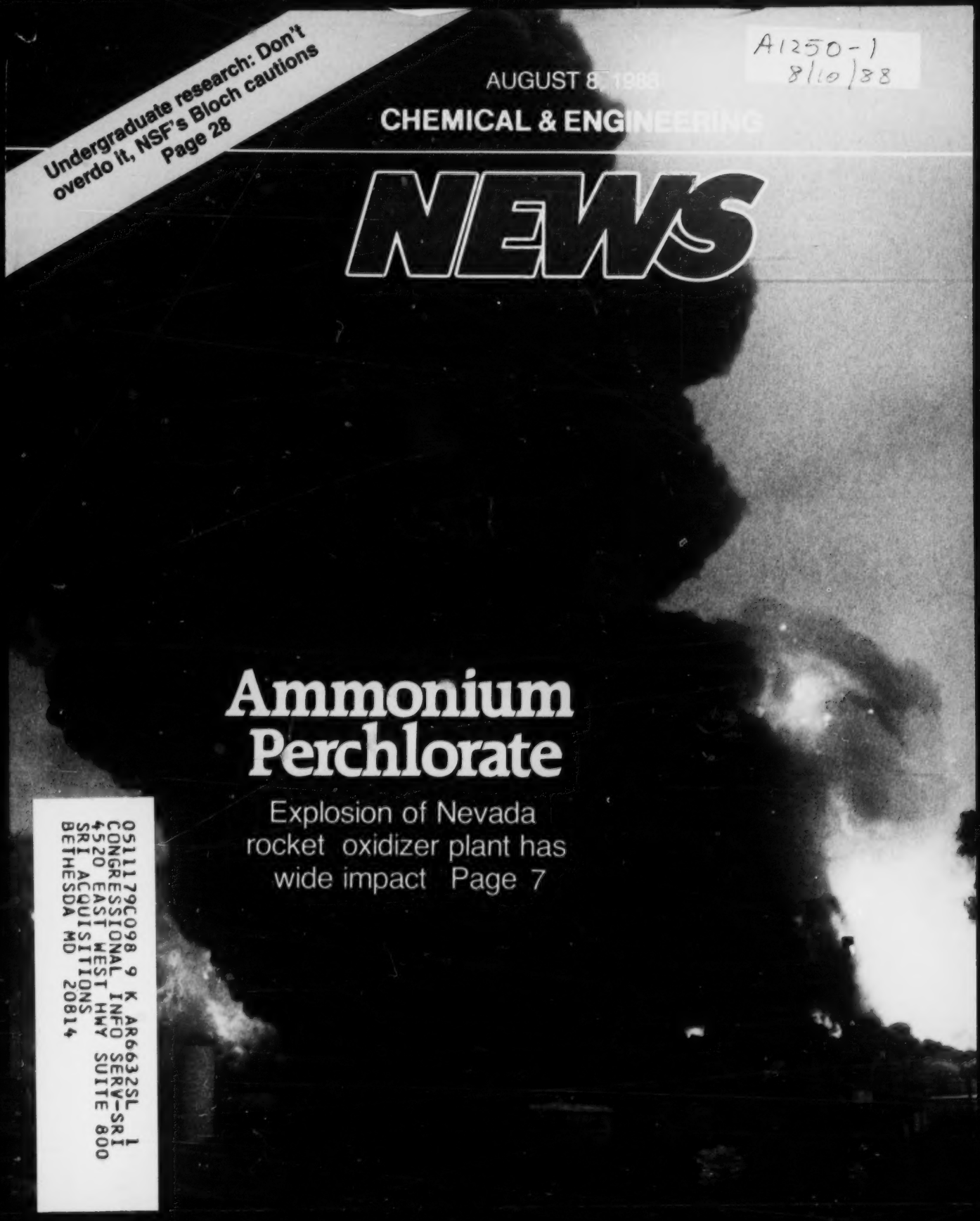
AUGUST 8, 1988

CHEMICAL & ENGINEERING

NEWS

Undergraduate research: Don't overdo it, NSF's Bloch cautions Page 28



Ammonium Perchlorate

Explosion of Nevada rocket oxidizer plant has wide impact Page 7

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CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 32
CENEAR 66 (32) 1–56
ISSN 0009-2347

AUGUST 8, 1988

News of the Week

■ **Natural Resources Defense Council asserts EPA's final rules on cutting production of CFCs will not protect the stratospheric ozone layer, as required by law.** **Page 4**

■ **Purchase of Koppers Chemical by its own management and Gordon Cain has been canceled because of potential environmental liabilities.** **Page 5**

■ **Iraq continues to use chemical weapons as U.S. attempts to move negotiations forward for a global treaty on such weapons.** **Page 5**

■ **Congress passes internationally controversial trade bill, which displeases Japan and Europe but boosts U.S. labor, industry.** **Page 6**

■ **Two candidates for ACS posts have been nominated by petition.** **Page 6**

Cover: Third in a series of explosions on May 4 that destroyed ammonium perchlorate plant in Henderson, Nev., owned by Pacific Engineering & Production Co. of Nevada. Photo by Arthur C. Strandberg

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Business

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Government

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Science

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Education

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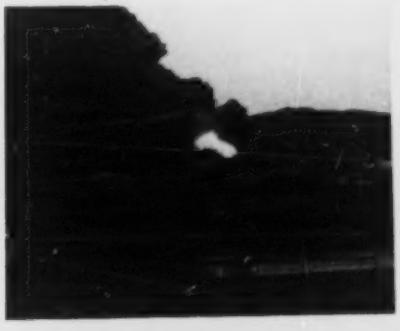

News Focus

Explosion at Henderson, Nev., rocket oxidizer plant in May has raised concerns about supply of ammonium perchlorate and caused widespread fear among residents of Henderson, where second oxidizer plant still operates. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

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Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jeanne M. Shreeve; and Barbara G. Wood

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Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

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LETTERS

CHEMICAL SAFETY

Toluene and sulfur dichloride

SIR: This letter is to alert interested parties to an exothermic reaction between toluene and sulfur dichloride. This reaction is accelerated greatly in the presence of iron or ferric chloride.

Recently, a serious incident, including a vessel rupture from overpressurization, occurred at one of our facilities when toluene was added to a carbon steel head tank containing sulfur dichloride.

Subsequent hazards laboratory testing revealed that an exothermic reaction occurring between toluene and sulfur dichloride is catalyzed by iron or ferric chloride.

We have concluded that the pressure generated by this catalytic reaction caused the head tank rupture, fatally injuring one employee. References to this catalytic reaction were not found by extensive searches of the literature.

Joseph C. Caporossi
Manager, Safety, Health, and Emergency Response
American Cyanamid Co.
Wayne, N.J.

Editor's note: According to Occidental Chemical Corp.'s material safety data sheet, conditions contributing to the instability of sulfur dichloride include heat, exposure to moisture, and contact with alkalies or organic matter. Keep lights, flames, or sparks away from the drum or tank opening, since flammable hydrogen gas may be formed upon the reaction of sulfur dichloride with steel in the presence of moisture. Sulfur dichloride reacts vigorously with strong alkalies, water, and other alkaline chemicals. Hydrolysis of sulfur dichloride in the presence of water can release hydrogen chloride, sulfur dioxide, and hydrogen sulfide.

2-Indanecarboxaldehyde

SIR: We recently had occasion to prepare a small quantity of 2-indanecarboxaldehyde from 2-indanone via the well-precedented Wittig reaction with methoxymethylenetriphenylphosphorane followed by acidic hydrolysis of the intermediate enol ether. The reaction proceeded normally until attempted bulb-to-bulb distillation of the crude product (about 2 g) using a Kugelrohr apparatus. At 70 °C and 0.1 torr, just as the product was beginning to distill, a violent detonation occurred, which pulverized the glass flask and totally destroyed the distillation apparatus. Fortunately, the apparatus was in a good hood and the student carrying out the procedure was not adjacent to the incident. Had he been looking into the Kugelrohr at the time of the explosion, serious injury would very likely have resulted despite the use of safety goggles.

Since the reaction sequence employed for this transformation is widely employed, we must assume that the compound itself is thermally unstable either in its own right or as a result of contamination by reaction by-products. No residue was available for analysis.

It is known that cycloalkyl carboxaldehydes decompose with time and are generally difficult to purify, but we have successfully distilled both cyclohexane- and cyclopentanecarboxaldehyde on numerous occasions with no incident. Since we have been unable to rationalize this incident in terms of the causative factors, we are discontinuing the distillation of 2-indanecarboxaldehyde and recommend that others do likewise.

T. Howard Black
Associate Professor
Eastern Illinois University

Selenium levels decreasing

SIR: F. Henry Firsching's warning of coal's negative environmental impact (C&EN, June 20, page 3) is well taken in regard to the greenhouse effect. Added to this is the growing evidence that acid rain is a major factor causing reduced plant uptake of the essential element selenium. Finland now requires the addition of selenium to fertilizer, and the Food & Drug Administration has trebled the level of selenium permitted to be added to animal feeds. The various reasons, including acid rain, why the level of selenium in the food chain is decreasing are well documented.

Development of the hypothesis as to why the air to soil to plant to animal

Correction

• July 25, page 2: In Lyell Carver's letter, a typo in paragraph four changed the one-sixth share each of three children would inherit to one-sixteenth.

CFC PRODUCTION CUTS: EPA rules already under attack

No sooner did the Environmental Protection Agency issue final rules on cutting chlorofluorocarbon (CFC) production last week than it was hit with the threat of a lawsuit by the Natural Resources Defense Council. The national environmental group asserts EPA's regulations will not protect the stratospheric ozone layer, as required by law, or even keep the current depletion problem from getting worse.

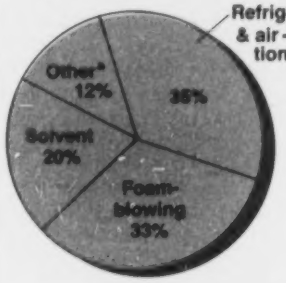
The new EPA regulations echo the terms of the Montreal Protocol on Substances That Deplete the Ozone Layer, the international agreement to control the output of both CFCs and halons (fluorocarbons that contain bromine atoms). Production of CFCs is to be frozen at 1986 levels on July 1, 1989. CFC output is to be cut 20% by mid-1993, then an additional 30% by mid-1998. Halon output is to be frozen at 1986 levels on July 1, 1989.

For the Montreal Protocol to go into effect on schedule, it must be ratified by at least 11 countries accounting for two thirds of world consumption. Six countries (Mexico, the U.S., Canada, Norway, Sweden, and New Zealand) already have done so. Japan and the European Community are expected to ratify the pact shortly, putting the count over the top. The new EPA rules will go into force when the protocol does.

"These regulations are a helpful start, but the reductions are too little and too slow to protect the public health and the ozone layer," says NRDC senior project attorney David A. Wirth. Because fully halogenated CFCs have such long atmospheric lifetimes, the chlorine content of the atmosphere will continue to increase for many years despite the scheduled production cuts.

"EPA's own calculations say an 85% intermediate reduction is needed to keep the atmospheric concentration of chlorine from increasing," Wirth points out. Scientists studying the ozone problem have repeatedly stated that even at today's concentrations, chlorine-catalyzed reactions are causing massive losses of ozone over Antarctica and have been implicated in smaller decreases in ozone throughout the rest of the globe (C&EN, March 21, page 6). Thus, Wirth argues, the U.S. should unilaterally impose sharper reductions in CFC use.

Cooling, foam-blowing are largest U.S. CFC uses



1986 total consumption = 670 million lb

a Includes aerosols, sterilization, food freezing, and other miscellaneous uses.
Source: Environmental Protection Agency

EPA has considered and rejected the strategy of acting alone, preferring to work toward a stronger international agreement, says Eileen Claussen, the agency's acting deputy assistant administrator for air and radiation. "We would like to push other nations so that we end up with a protocol that goes to a 95% cut," she says. "In the end we'll be more successful if we move with the rest of the world." EPA plans to be a forceful presence at an international meeting set for October in the Netherlands at which the nations that have signed the Montreal Protocol will consider whether it needs to be strengthened, she says.

Meanwhile, EPA is considering whether to modify the way in which it has decided to control halocarbon output. The agency has given the seven firms that make halocarbons in the U.S. rights to produce them in the future. The quotas have been allocated in proportion to each firm's share of the market for 1986. U.S. CFC producers are Du Pont, Allied-Signal, Pennwalt, Kaiser Chemicals, and Racon. Besides Du Pont, Great Lakes Chemical Corp. and ICI Americas make halons.

Now the agency is pondering whether to impose a regulatory fee on the producers in order to recoup windfall profits that might be an unintended result of the quota system. As the supply of CFCs shrinks, prices may increase as much as fivefold, according to EPA. The agency estimates producers could earn an additional $2 billion to $7 billion as prices rise, depending on how fast CFC users switch to other technologies and substitute products.

"We're afraid if the producers are making a lot of money off of the existing CFCs, there won't be an incentive to come up with substitutes," Claussen says.

Du Pont, the world's largest CFC producer, insists no furthur incentives to move to substitutes are necessary, pointing out that it has already pledged to get out of the business entirely. "We expect to be able to complete our phaseout by the year 2000," says Joseph M. Steed, environmental manager for Du Pont's Freon Products Division. "Producers are already stumbling all over each other racing for new alternatives."

Pamela Zurer

Impact Widening from Explosion Of Nevada Rocket Oxidizer Plant

PEPCON starts to rebuild wrecked Henderson unit at distant site, but concern rises over supply of ammonium perchlorate; residents fear danger from Kerr-McGee perchlorate plant still in their midst

Richard J. Seltzer, C&EN Washington

Three months ago, shortly before noon on May 4, the town of Henderson, Nev., was rocked by a series of explosions at a plant owned by Pacific Engineering & Production Co. of Nevada (PEPCON). The impact was immediate and dramatic, and is still widening.

On one level, the disaster created a critical national problem. What went up in smoke and flame in a matter of minutes was an inventory of more than 8 million lb of ammonium perchlorate (AP), and approximately half the U.S. capacity for making this oxidizer used in solid-fueled rockets (C&EN, June 13, page 9). The accident has raised concerns in government and industry about allocation and supply of AP and the impact on national space and missile programs. Plans are in the works for restoring production at PEPCON and for expanding AP capacity at the only other U.S. producer, Kerr-McGee Chemical Corp., also sited in Henderson.

On another level, however, PEPCON, Kerr-McGee, and Henderson furnish an intriguing case study of relations between chemical industry and a community. The series of blasts killed two PEPCON senior executives, injured more than 350 local residents, and caused damage estimated to exceed $73 million (C&EN, July 4, page 5). Lack of federal aid has upset the community, and fear and concern are widespread about the Kerr-McGee plant still operating in Henderson.

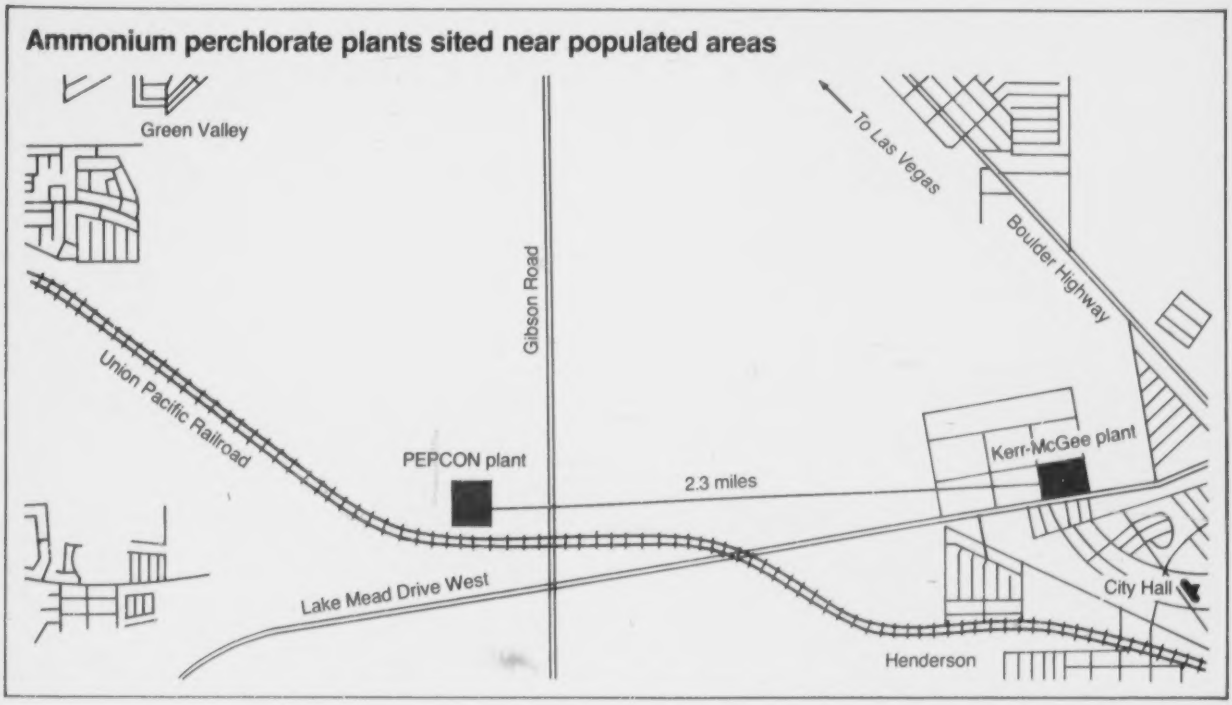
The disaster that leveled PEPCON's ammonium perchlorate plant only took about 15 minutes—from the first fire to the last of the explosions. One company worker describes his experience this way:

"I was working and I heard a few pops. Then there was a bigger explosion and the ceiling fell down, and I was almost knocked out. I didn't know what was happening, but I heard someone yelling that there was a fire in the plant. Everyone was running out as fast as possible. Flames were shooting 50 to 100 feet into the air. So I ran away from the building.

Photo by Arthur C. Saunders

Second in series of explosions erupts at 11:58 AM on May 4 at PEPCON'S perchlorate plant in Henderson

"I got to my truck, but the hood was already on fire and I couldn't put it out. Then I felt the hottest heat I've ever felt. The whole lot was full of AP and I saw most of the AP stored was on fire. My face got sunburned, it was so hot. I ran to about 25 yards away from the storage field and there was a second explosion. I was thrown through the air by the shock wave. I was covered with greyish-white smoke, and had a burning sensation and trouble breathing. I got up again and ran some more. There was a constant rain of dark grey grit, probably asphalt from where the AP was stored. I got further away and there was a third explosion, again throwing me. Finally, I got about 350 or 400 yards away and started to walk. That's when

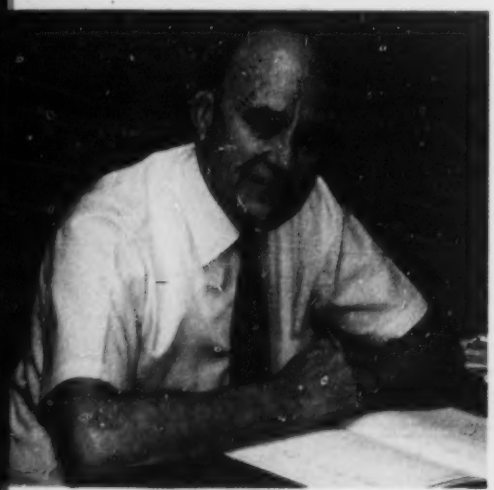


the final explosion came. It was the biggest of all—it was just incredible. The shock wave goes through you like electricity, and the whole ground was shaking."

Left behind in ruins was a plant that had been making 24 million lb a year of the solid fuel oxidizer, with a capacity for up to 40 million lb. It was the principal supplier of AP for the space shuttle's solid rocket boosters. And it was the sole supplier for the largest U.S. unmanned rocket, Titan IV; for the most widely used naval tactical system, the Standard Missile; and for the second stage of the Peacekeeper (MX) missile. PEPCON had 48 plant workers on site, with 60 administrative personnel.

The firm was started in November 1955 by three men, including the father of the current chairman, president, and chief executive officer, Fred D. Gibson Jr. The trio had left their positions as officers, owners, and directors of Western Electrochemical Co. (WECCO), which had built the first AP production facility in the U.S., after WECCO was acquired by American Potash. Gibson Jr. also left WECCO for PEPCON.

PEPCON's successful research on a platinum substitute anode for perchlorate production led it to build an AP pilot plant in 1958 at the current site on Gibson Road in Henderson. The firm expanded to a capacity of 5.5 million lb a year in 1959 and 11 million in 1961.



Gibson: AP production in six months

C&EN staff photos

Green Valley resident Walz (left) and Rep. Roe speak at House subcommittee hearing in Henderson

At that time, three firms made AP besides PEPCON: American Potash, Pennsalt Chemicals (later renamed Pennwalt), and Hooker Chemical. The market was not big enough to support four firms, however, and Pennsalt and Hooker dropped out in the mid-1960s. American Potash was acquired by Kerr-McGee in 1967, leaving PEPCON and Kerr-McGee as the only two producers. Both firms were encouraged to expand with federal aid as the space shuttle program geared up in the early 1980s. PEPCON raised capacity to 40 million lb a year and Kerr-McGee to 36 million.

In 1982, PEPCON merged with and became a subsidiary of American Pacific Corp., a publicly owned corporation (traded over the counter) also headed by Gibson. His brother, James I. Gibson, serves as executive vice president of both PEPCON and American Pacific, and wields considerable influence as a senior member of the Nevada state Senate. The firm carries on two other businesses: pollution control equipment and engineering services, adapting electrochemical technology used in AP production; and development of an industrial/commercial park, Gibson Business Park, in Henderson.

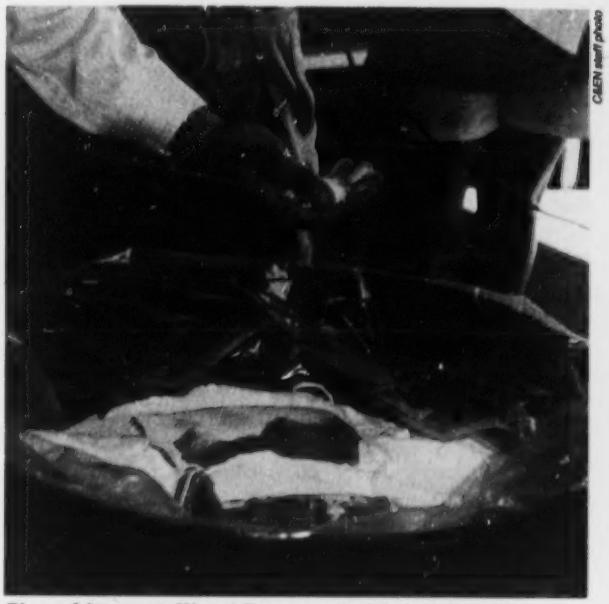
Both AP plants—PEPCON's and the Kerr-McGee unit about 2.3 miles away—were built in the Las Vegas suburb because of two advantages: inexpensive hydropower for the electrolytic processes from nearby Hoover Dam; and a dry desert climate permitting easier handling and storage of the hygroscopic product.

Production of ammonium perchlorate, NH_4ClO_4—a white, crystalline substance—involves relatively simple chemistry. First, sodium chloride is converted to sodium chlorate and then to sodium perchlorate in two electrolysis steps. Next, sodium perchlorate is reacted with ammonium chloride (formed from ammonia and hydrochloric acid) in a double exchange reaction to yield AP and sodium chloride.

However, Gibson tells C&EN, "it's as much an art as a science." The art, generally held proprietary, includes controlling such parameters as particle size distribution, particle shape, purity, and moisture content to achieve desired specifications.

Kerr-McGee uses a continuous process, whereas PEPCON employs a batch process. One advantage of the batch process, says Raymond C. Rhees, PEPCON's vice president for R&D, is that it allows better tailoring of crystallization to produce a desired particle size distribution. This means less blending is required and lower inventories can be kept.

AP is a critical component of a stunning variety of solid fuel rockets used for space programs and for strategic and tactical military uses. For example, AP constitutes about 70% of the solid propellant in space shuttle booster rockets. The pair of booster rockets used for each shuttle launch consumes about 1.7 million lb of AP. The Air Force's workhorse Titan IV unmanned rocket, by contrast, uses less than half as much AP, 800,000 lb per launch. AP has ideal properties for a rocket oxidizer, yielding all gaseous products and possessing a high flame temperature, notes pyrotechnics expert John Conkling of Washington College, Chestertown, Md.



C&EN staff photo

Fine white crystalline AP is stored with dessicant in plastic-lined barrel until crossblended at Kerr-McGee

Figures collected recently by the Defense Department estimate total U.S. demand for AP at 38.8 million lb in 1988, rising to 60.1 million lb in 1989 with expected resumption of shuttle flights and other missions. With only the Kerr-McGee plant now producing, and with a capacity of 36 million lb a year, many observers fear that the U.S. may face a crisis of short supply in its space and missile programs over the next three years.

The problem is not only quantitative, but qualitative. Only PEPCON has passed qualification requirements to supply AP for the Titan IV, Standard Missile, and several other rockets: Product could not be diverted from Kerr-McGee for these rockets without going through qualification tests taking many months.

A recovery strategy—with plans for rebuilding production and setting of priorities for supplies in the meantime—is being formulated by an ad-hoc interagency working group. On it are representatives from the National Security Council (NSC), office of the Secretary of Defense, Air Force, Joint Chiefs of Staff, National Aeronautics & Space Administration, Department of Transportation, Office of Management & Budget, Department of Justice, Federal Emergency Management Agency (FEMA), Department of Energy, Department of Commerce, and Department of State.

This working group has sent recommendations to NSC, and that council has made some decisions on near-term allocations. The good news is that officials believe the supplies on hand in inventory and being produced by Kerr-McGee will be able to cover all AP requirements in 1988, although some schedules may have to be stretched out. The bad news is that a crunch is likely next year and the year after, until PEPCON starts supplying AP from a new plant and Kerr-McGee expands its output.

Morton Thiokol, producer of the shuttle booster rockets for NASA, already has enough AP on hand for a remaining on-ground test firing and for the first four shuttle flights. The explosion at PEPCON destroyed AP already produced and being readied for shipment to Thiokol for the fifth and sixth shuttle launches. Therefore, NSC has given top priority to the fifth shuttle launch. Kerr-McGee is already delivering AP to Thiokol to prepare for that flight, scheduled to carry the Magellan spacecraft during a "launch window" next April to orbit Venus. It will use high-resolution radar to obtain detailed images of the planet's surface through its thick clouds of sulfuric acid and carbon dioxide.

The next AP delivery from Kerr-McGee will go to the Department of Defense (DOD) for a Titan 34D launch. And NSC has formulated a plan to handle the rest of AP demand this year. DOD is finalizing this document and will soon send it to the Commerce Department's Office of Industrial Resources Administration. This office is charged under the Defense Production Act of 1950 with overseeing production and distribution of critical materials to meet defense, space, and other needs.

The big question is what happens in the next couple of years? How long will it take PEPCON to start production and to pass NASA and DOD qualifying tests for use of its AP? When will Kerr-McGee begin expanded production? The working group will meet next month to start considering allocations for the first six months of 1989.

The most optimistic assumption is that PEPCON can resume production and pass qualifying tests by next summer, and that Kerr-McGee will expand its capacity with a new facility by then. If this can be done, says Daniel S. Rak, deputy assistant secretary of the Air Force, who chairs the AP interagency working group, it may be possible to reduce the AP shortfall in 1989 to less than 3 million lb out of a demand of 60 million.

Allocation planners will try to maintain maximum flexibility. For example, if shuttle flights are backed up and have to be postponed, planners will examine the possibility of shifting AP in the meantime to another user. Another option to be investigated is whether some payloads could be moved from the shuttle to unmanned rockets using half as much AP or less.

However, says Adm. Richard H. Truly, NASA's associate administrator for space flight, "remanifesting and delay of some space shuttle flights are probable" next year. NASA will focus on a series of flights to carry "our most precious payloads"—bearing major scientific missions such as Magellan and the Hubble Space Telescope. Moreover, the working group projects insufficient supplies of AP for some planned flights of Titan IV and Titan 34D.

Federal officials have also looked at a longer-term possibility—enlisting a third AP producer—going so far as to talk to two firms that used to make AP, according to an industry source. However, the firms were not interested. Indeed, several observers doubt the market would be profitable if split among three companies. Import of AP from abroad is also not considered a viable option, since foreign production capacity is relatively small.

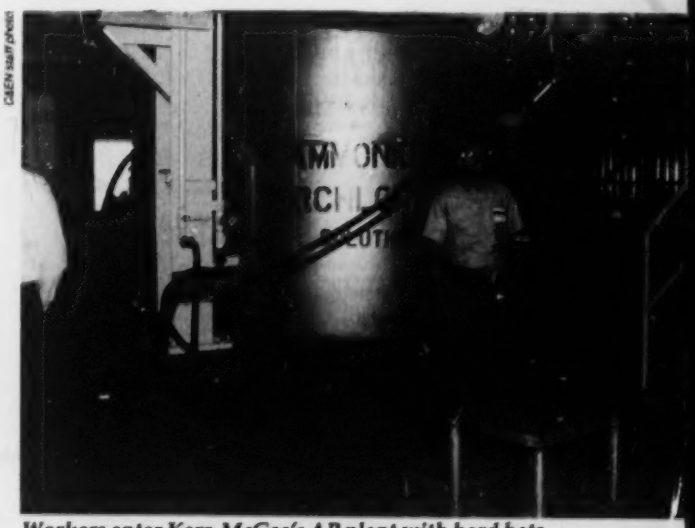
C&EN staff photo

Water Street runs through center of Henderson, Nev.

In any case, the centerpiece of the recovery program is expansion by Kerr-McGee and rebuilding of a plant by PEPCON. By a small modification—eliminating the redissolving and reuse of "screen reject" AP particles from customers--Kerr-McGee expects to be able to raise the capacity of its current plant from 36 million up to 40 million lb a year. In addition, it plans to build a new plant with 20 million lb-a-year capacity, using the same process, at some site remote from Henderson.

Both this plant and a 40 million lb-per-year plant to be built by PEPCON will benefit from federal aid. The two firms will borrow funds on their own for construction, and the loan will be repaid over seven

C&EN staff photo



Workers enter Kerr-McGee's AP plant with hard hats, safety goggles, respirators, and safety galoshes

years through a surcharge on each pound of AP sold, based on sales of 20 million lb a year. The federal government guarantees to pay any unamortized amount at the end of seven years.

PEPCON is moving ahead rapidly with its rebuilding plans. Gibson stresses that the firm has committed itself in writing to NASA, DOD, and Thiokol to start producing AP in six months, by Feb. 1.

To build and run the new plant, American Pacific organized a new subsidiary, PEPCON Production Inc. (PPI). PEPCON is likely to be tied up in litigation over damage suits for years, and carried liability insurance of only $1 million. Bankruptcy is a distinct possibility. The new subsidiary signed a license agreement buying PEPCON's technology for a royalty of $0.005 per lb of production.

Late last month, the firm selected a remote, 4800-acre mountain valley site 15 miles west of Cedar City, Utah. There is only a dirt road to it, but it has a railroad line, power lines, and a water source. The site is about 175 miles from Henderson, notes Rhees, but beat out two remote Nevada sites because construction could proceed there on the required expedited basis. A few days earlier, a special session of the Utah legislature approved a $33 million industrial revenue bond issue to finance construction of the plant. Design and construction, at an estimated cost of $23 million, will be carried out by Stearns-Rogers.

Several sources express great skepticism that PEPCON can build the plant and start production within six months, one calling the idea "preposterous" and saying it should take at least 12 to 18 months. However, Gibson explains, several measures will expedite his plans.

For one thing, the company will initially buy sodium chlorate, which is readily available, and convert it to sodium perchlorate and then to AP at the new plant. Eventually, the firm will make feedstock sodium chlorate at another site, in southern Nevada, so it can take advantage of low-cost power from Hoover Dam, according to Rhees. The major power cost in preparing AP is adding three oxygen atoms to sodium chloride to form sodium chlorate, he points out. Putting on the fourth oxygen to make the perchlorate in Utah will cost much less. PEPCON will then transport the sodium chlorate in solution to Utah, a less hazardous method than transporting the solid.

Moreover, Gibson says, the plant does not have to be complete initially. It can be built in modular form—installing, for example, half the crystallizers initially and adding the rest later. The plant will use the same process and design plans as the destroyed plant, with introduction of more automated process control. PEPCON has a large cadre of personnel familiar with the plant design and operation. Initially, the plant will employ about 70 people, growing later to 150.

In response to skeptics, Gibson also emphasizes that PEPCON is committed to furnish product "meeting specifications" within six months, but that period does not include qualification of the product. He expects, for instance, that NASA will insist on a full set of tests to qualify AP for use in shuttle booster rockets, from lab to full scale, which could take at least several months.

Photo by Raymond C. Rhees

At wrecked PEPCON plant, polyethylene drums burned away, leaving behind unreacted piles of AP stored in them

Possible delays, stretchouts, and cancellations in space and missile programs due to a shortage of AP have aroused great concern among rocket users and manufacturers, rocket fuel makers, and their insurance companies. For example, PEPCON has been the sole source of AP for Aerojet-General Corp., maker of Stage 2 of the MX missile, and the Hawk, Standard, Maverick, and other missiles. Aerojet has enough AP on hand for the near future. But if PEPCON does not start producing on Feb. 1 as it says it will, "there could be problems," Aerojet says.

As for the months of qualification tests a new PEPCON plant might face, "you can speed up the qualification process if there's a national emergency," an Aerojet spokesman points out. His firm is also looking into possible supply from Kerr-McGee.

Meanwhile, potential participants in the fledgling U.S. commercial space launch industry are deeply concerned about what priority commercial space launches will receive in allocations of limited AP. For example, satellite maker Hughes Aircraft Co. has contracted with rocket manufacturers Martin-Marietta and McDonnell-Douglas to use their commercial launch vehicles, the Titan III and Delta II, respectively, to put British and Japanese direct broadcasting satellites into orbit. If the British launch, scheduled for August 1989, is delayed, Hughes stands to lose $100 million on a deferred payment contract. Delay of six to 12 months in the July 1989 Japanese launch could cause losses of $70 million or more.

Hughes says it hasn't received a definitive answer yet. But there are indications that when the interagency working group meets in September to plan AP allocations for the first half of 1989, the group will try to accommodate commercial launches, especially where the future of a business may be at stake.

The blasts at PEPCON on May 4 had a dramatic impact not only on national needs and issues. They also injured some 350 local residents, caused harm to

property up to 20 miles away, and did some damage to more than 50% of Henderson's 17,000 residential and commercial buildings. The two largest blasts registered 3.0 and 3.5 on the Richter scale hundreds of miles away in California, notes Nevada Gov. Richard H. Bryan. Cars were crumpled, doors blown off their hinges, and windows shattered for miles around. Particularly hard hit was the Green Valley subdivision, just a mile and a half from PEPCON.

City Manager Gary Bloomquist puts uninsured losses at more than $20 million, plus $3 million more in insurance deductibles. Just as serious, he says, were the psychological and emotional impact of the explosions, on schoolchildren and adults alike. And many residents call the disaster "miraculous," because a chain of lucky events prevented almost all loss of life or more serious damage.

The disaster brought a kind of end to innocence for some residents, an awareness for the first time of the presence and potential hazards of chemical plants, and the need for more regulation and oversight. These feelings of concern and fear—particularly about the presence of the Kerr-McGee plant, just 0.7 mile from the center of town—were vehemently expressed by several local citizens and leaders at a hearing a few weeks ago in Henderson, held by the Subcommittee on Investigations & Oversight of the House Committee on Science, Space & Technology. The committee and subcommittee chairman is Rep. Robert A. Roe (D.-N.J.).

For example, Pamela Walz, a Green Valley resident, described the traumatic events of May 4 and $7500 in damage done to her 10-month-old house, and admitted that she had never before heard the names PEPCON and ammonium perchlorate. Next, she discovered that there was another plant in Henderson, Kerr-McGee's, that made the same product. Then she learned that "there are many chemical companies in the industrial complex, but no one had any idea what they manufactured."

C&EN staff photo

AP is stored outdoors in 30- and 50-gallon barrels at Kerr-McGee to await blending to desired specifications

She realized that the tankcars on the Union Pacific Railroad spur that served PEPCON and other chemical firms also ran by her house several times a day. She contacted several government agencies until she obtained a list of some of the chemicals transported. And she concluded that "no government agency on any level has the ability at this time to monitor the transportation, manufacture, or storage of chemical compounds in this state. The few regulations we do have regarding safety and environmental concerns are flagrantly violated because the penalties are insufficient."

Echoing the opinion of many others, Walz noted that she supports strong defense and space programs. However, she does not believe she and her fellow residents should have to bear alone the risk and financial burden of chemical disaster. "I was never given a choice on whether to risk the health and safety of my family. I feel that we can produce ammonium perchlorate in Nevada, and possibly in Clark County [her county]. But not in the middle of a city of 56,000 residents."

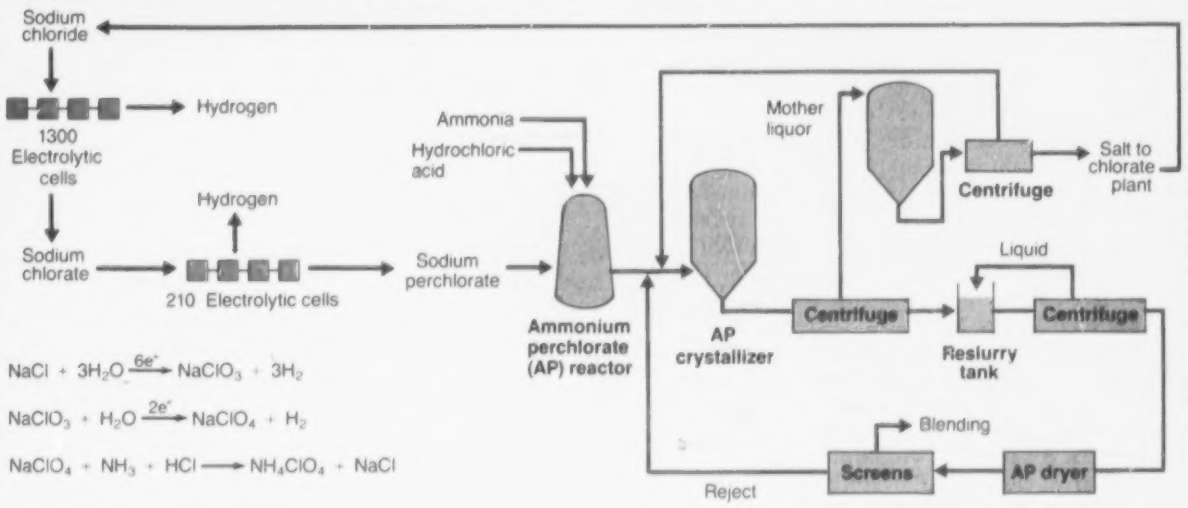
What particularly upset her and other Henderson residents was that, on the one hand, NASA and DOD have "irresponsibly" decided to give a subsidy of tens of millions of dollars for rebuilding the PEPCON plant and constructing an additional Kerr-McGee plant, "without stipulating safety factors regarding the plant employees and the community." But on the other hand, the Federal Emergency Management Agency (FEMA), after three visits to Henderson, has denied any disaster aid to local residents.

Her words were reinforced by those of Brian Greenspun, president of the *Las Vegas Sun* newspaper, expressing, he said, "a consensus" of local residents. Few other communities have been asked to give so much or to take such risks as Nevadans have in the name of patriotism, he says. The state's land is 87% owned by the federal government. It has hosted aboveground and underground nuclear testing, the Nellis Air Force weapons training base, and now it is having pushed on it a nuclear waste disposal dump at Yucca Mountain.

Nevadans are being asked to "accept the unacceptable risks of living amidst the production of ammonium perchlorate, whose explosive potential has been demonstrated in living color on the television sets of the world," Greenspun continues. "The people of Las Vegas are frightened," he adds. They are no longer willing to accept the assurances of government, particularly when those who have lost their life savings or even just had to pay their insurance deductibles are told that "the risk of such explosions is theirs alone and not to be shared by the government in whose name these plants exist." And he urges a government financial package to move the AP plants to a safer, more remote site.

Roe and his staff aides have made considerable efforts to arrange financial aid for Henderson residents who suffered damage from the disaster, as has Rep. James H. Bilbray (D.-Nev.), who represents the area in Congress. Roe wrote in June to President

Kerr-McGee uses two electrolysis steps and double-decomposition reaction to make ammonium perchlorate



Kerr-McGee Chemical Corp. uses several unit processes to produce ammonium perchlorate (AP). First, in a continuous process using large holding tanks, sodium chloride is electrolyzed to sodium chlorate in some 1300 cells. By-product hydrogen, containing a trace of chlorine, is vented to the atmosphere. The chlorate is crystallized out, redissolved, and then electrolyzed further to produce sodium perchlorate in a batch process in some 210 cells. Sodium dichromate is added to enhance cell efficiency. The perchlorate is filtered out and purified. AP is then produced from sodium perchlorate, anhydrous ammonia, and hydrochloric acid by a double-decomposition reaction. In a vacuum crystallizer—operated so as to produce the desired particle size—AP precipitates and sodium chloride stays in solution. AP crystals are centrifuged out, reslurried, and pumped to a remote building for drying and screening. Finally, AP is blended to specifications for particle size and purity, packaged, and shipped. By-product sodium chloride returns to the sodium chlorate plant for reuse.

Reagan, urging that FEMA grant disaster relief. "A community that supports two of the most important plants in the country has suffered misfortune as the result of that support and should be treated with compassion and concern," Roe wrote.

Nevertheless, FEMA denied such aid. Roe and Bilbray, therefore, are now preparing to submit bills to grant compensation to local residents for some $2.5 million in insurance deductibles. In addition, Roe and his staff have been working to persuade the Nevada state legislature to aid the victims. At a meeting this week, the state's interim finance committee will consider compensating the Henderson city government and the Clark County school system for between $400,000 and $600,000 in damages and services related to the disaster.

The remaining segment of the population not yet covered is those who were uninsured. Also through the offices of Roe and Bilbray, Kerr-McGee announced late last month formation of a $293,000 loan guarantee program to offer 10-year loans at favorable interest to uninsured residents and businesses who suffered damage from explosion of the PEPCON plant. PEPCON is working on setting up such a fund, but its poor financial position has prevented it so far from working out an arrangement with local banks.

Kerr-McGee's decision to create the fund, despite its lack of connection with the May 4 explosions, is part of a recent policy by the firm of reaching out to better its relations with the local community. After the PEPCON disaster, local pressure forced Kerr-McGee to shut down its AP plant for several weeks while an independent safety panel inspected the facility and recommended changes. There was even concern in Congress and elsewhere that local residents might seek injunctions to keep the plant closed, and discussion of whether the federal government might have to invoke national emergency powers to keep open the only source of AP in the U.S. Considerable local sentiment still wants the plant moved out of town.

Before reopening in June, the plant adopted eight improvements urged by the safety panel, and it is now working on others of a longer-term nature. The plant is also increasing the dispersal of barrels of AP stored outdoors, as requested by local fire officials. And it is buying an additional blender to expedite shipments and enable reduction of stored inventory on site.

In late June, Kerr-McGee invited local media in to tour and photograph its AP plant and to interview plant managers. The managers put great emphasis on all the safety measures at the plant. And they indicated that the media visit was a "first step on the trail of being more open."

Furthermore, Kerr-McGee has hired an advertising

agency to help get the firm "more involved with the community"—including newspaper ads to better its image—and to give it more feedback on community concerns. And the firm plans to seek cooperation from DOD, the Department of Transportation, NASA, academia, and rocket motor makers for joint studies on a large scale to determine safe ammonium perchlorate storage and shipping practices.

However, Kerr-McGee's efforts to maintain a safe image were not aided by its citation, just revealed last week, for seven alleged violations and $5200 in fines by the Nevada Division of Occupational Safety & Health (DOSH), which fills the role of the federal Occupational Safety & Health Administration in Nevada. One "willful" violation involved exposing workers to "increased likelihood of fire and explosion hazards" by manufacturing, processing, and storing AP in areas with potential for contamination with organic materials. A "serious" violation involved not keeping work areas clean of AP in spills, leaks, and dust.

Kerr-McGee was also cited for exposing employees to the "likelihood of fire and explosion hazards" by storing AP improperly: 26 million lb were stored in piles in close proximity outdoors and on asphalt pads. "AP and asphalt are incompatible," DOSH says, because asphalt must be kept away from strong oxidizers. Kerr-McGee has taken action to correct six of the seven violations, but will appeal the asphalt charge.

Meanwhile, DOSH has also just cited PEPCON for 30 alleged safety violations and levied $36,455 in fines, on the basis of an investigation since the disaster about conditions before it. Several of the violations resemble charges hurled at PEPCON in the controversy over what caused the disaster.

Thus, the four "willful" citations include lack of manufacturing controls and standard operating procedures that caused employee exposure to "increased likelihood of fire and/or explosion"; and lack of emergency evacuation and response procedures for workers in event of an accident. One of the nine "serious" violations was improper storage of large quantities of AP, in disregard of safe quantity/distance requirements, and storage on asphalt pads. Gibson says that PEPCON will appeal the charges, terming them based on "unsubstantiated allegations."

Probably the greatest source of controversy in Henderson now is what caused the disaster at PEPCON, with millions of dollars in liability lawsuits riding on the outcome. Indeed, the first personal injury suit was filed on May 5, the day after the disaster. An independent panel sponsored by the local fire department is analyzing the origin and propagation of the fire and explosions. Investigations are also being done by an independent panel engaged by PEPCON and its insurance company, by other insurance companies, and by Southwest Gas Corp.

In mid-July, the Clark County Fire Department issued a one-and-a-half page interim report, blaming a combination of factors for the disaster—welders cutting in a hazardous area with no fire watch, highly combustible structural components (glass-fiber reinforced plastic), high-density storage of "a highly flammable and detonable material," spilled AP lying around, and high-velocity wind conditions.

According to the report, PEPCON welders working at the west end of the batch dryer house sprayed iron slag, igniting combustible construction components, product process equipment, and residual AP in and around the batch house. The fire immediately spread "along available fuel surfaces," and by thermal expo-

Two firms qualify to supply perchlorate for rockets

System for which qualified	PEPCON	Kerr-McGee
Shuttle booster	•	•
Titan IV	•	
Titan 34D	•	•
IUS[a]	•	
Delta II		•
Peacekeeper (MX)		
Stage 1		•
Stage 2	•	
Stage 3		•
Small ICBM[b]		•
Minuteman		•
Trident D-5		•

a Inertial Upper Stage rocket, used for launches from space shuttle. b Intercontinental ballistic missile. Source: Department of Defense

Variety of rockets and missiles use ammonium perchlorate

AIR FORCE
- Advanced medium range air-to-air missile (AMRAAM)
- Air-to-Ground Missile (AGM-130)
- Delta II
- Inertial Upper Stage
- Maverick
- Minuteman
- Peacekeeper (MX)
- Sensor-Fused Weapon
- Short-range attack missile (SRAM II)
- Small intercontinental ballistic missile
- Titan 34D
- Titan IV

ARMY
- Chapparral
- Hawk
- 155MM high explosive shell
- Multiple launch rocket system (MLRS)
- Patriot
- Stinger
- Tactical missile system (ATACMS)

NAVY
- Harpoon
- High-speed antiradiation missile (HARM)
- Mk 46 Torpedo
- Mk 57 Bomblet
- Mk 48 Torpedo
- Mk 6/JATO (jet-assisted take off)
- Mk 23
- Mk 66
- Phoenix
- Quickstrike mine
- Rolling airframe missile
- Sidewinder
- Smokey Sam
- Sparrow
- Standard Missile Motors
- Sub-Launched Mobile Mine
- Tomahawk Cruise Missile
- Trident D-5

NASA
- Shuttle booster

Source: Department of Defense

Ammonium perchlorate use in rockets projected to reach 68 million lb by 1990. . .

Millions of lb	1988	1989	1990	1991	1992	1993	1994
Army	9.3	14.0	11.7	9.1	9.1	9.4	10.3
Navy	3.7	6.5	5.4	5.1	5.1	5.1	5.1
Air Force	11.0	11.5	16.1	12.9	10.0	10.0	10.0
NASA	6.5	19.8	22.1	24.2	28.0	31.3	29.7
Commercial space launches[a]	3.5	3.7	5.2	0.4	1.0	0.6	0.6
EMLRS[b]	1.8	2.6	5.3	5.3	7.0	5.3	5.3
Other export	1.0	2.0	2.0	2.0	2.0	2.0	2.0
TOTAL	36.8	60.1	67.8	59.0	62.2	63.7	63.0

a Use for commercial launches expected to grow in 1990s, but numbers available so far show only small demand.
b European Multiple-Launch Rocket System. Source: Department of Defense

. . .with shuttle booster taking the largest share

Millions of lb	1988
Shuttle solid rocket booster	18.8
Multiple launch rocket system (MLRS)	12.6
Titan IV	5.7
Minuteman	2.5
Standard missile	1.9
Trident D-5	1.5
Peacekeeper (MX)	1.6
Patriot	1.3
Delta II (GEM)	1.0
High-speed antiradiation missile (HARM)	0.8

Source: Department of Defense

sure and wind velocity spread to the adjacent storage of "high-density combustible containers of potentially detonable material." Several low-order explosions occurred, and the intense temperatures and direct flame impingement resulted in two major detonations in large aluminum tote bins holding up to 5000 lb of AP each.

Fire chief Roy L. Parrish tells C&EN that a consulting laboratory is running tests to determine the behavior of the materials involved, and the exact mechanism of the detonations. A detailed final report on the causes is due in mid-September.

Both PEPCON and the United Steelworkers Union local representing the welders and other company employees reject the interim findings. PEPCON says some of the findings "are inconsistent with the facts," and others "are inconsistent with established scientific data." For example, the firm believes the fire started at the east end of the batch house, 60 to 80 feet away from where the welders were.

A crucial element of contention is the properties of AP. PEPCON officials emphasize that AP is "an oxidizer that does not burn." When heated, "it provides oxygen to enable other materials that do burn to do so." If heated in a fire, notes Rhees, it contributes to the fire by releasing oxygen. Only when it gets to higher temperatures, approaching 430 to 450 °C, does it decompose violently. So the question is, he says, what was the fuel source that allowed the AP at PEPCON to get hot enough to explode?

The only fuel source known to be present in sufficient quantities was natural gas, PEPCON says. There was an underground 16-inch high-pressure gas main traversing the plant. "There is evidence of the presence of a large leak in the area preceding the incident," PEPCON maintains.

On May 4 there was a massive rupture several feet long in the gas line, with flames shooting 60 or 80 feet into the air from both ends of the rupture. And there is extensive evidence of fire emitting from the ground throughout the plant. In addition, PEPCON says, there is an abundance of physical evidence around the plant indicating the presence of natural gas fires.

"So it's not a question of whether there was a gas leak, but when it took place," says Gibson. There is considerable evidence, he notes, that there might have been a slow, small gas leak for up to two weeks before, possibly saturating the ground under the plant. A fire could easily start from such gas seeping out of the ground. Gibson says he expects in the near future to assert "a substantial claim for the company's losses in excess of insurance coverages against the party or parties responsible."

Southwest Gas retorts that "there is no evidence of any natural gas leak." Parrish confirms that the panel engaged by the fire department pressure tested all the gas lines at 10, 50, and 300 psi, and found no leaks except at the site of the massive breakage. Southwest asserts that its natural gas line was "the victim and not the cause of the blasts."

Southwest adds that research into the properties of AP indicates that only a very limited fuel source was necessary to trigger the initial explosion at PEPCON. There were numerous sources of fuel around, such as plastics, wood, hydrogen, glass fiber, welding gases, and contaminated AP. The initial explosion and fire could then have resulted in setting off the large quantities of AP stored on the site.

Until now, AP has been classified as an oxidizer, not an explosive, for purposes of transportation, handling, and storage. For example, the Department of Transportation (DOT) lists AP as an oxidizer for particle sizes greater than 15 μm, and as an explosive only at under 15 μm. PEPCON and Kerr-McGee work with far larger sizes (starting with 90 μm at PEPCON, for instance).

However, in light of the PEPCON disaster, re-evaluation of AP's properties and reclassification is being sought. Further testing is likely, according to several sources. For example, Bruce L. Woodbury, a county commissioner in Clark County, has written to the Air Force asking that AP be re-evaluated to see whether it should be reclassified as an explosive under applicable fire codes and standards. And DOT's Office of Hazardous Materials Transportation is waiting for determination of the causes of the PEPCON explosions before deciding whether to re-evaluate safety requirements for AP transportation. □